January 1973

EVALUATION OF PUREBREDS AND TWO-BREED CROSSES IN SWINE: FEEDLOT PERFORMANCE AND CARCASS MERIT

R. K. Johnson
University of Nebraska-Lincoln, rjohnson5@unl.edu

I. T. Omtvedt
Oklahoma Agricultural Experiment Station, Stillwater and U.S. Department of Agriculture, El Reno, OK, iomtvedt1@unl.edu

L. E. Walters
Oklahoma Agricultural Experiment Station, Stillwater and U.S. Department of Agriculture, El Reno, OK

EVALUATION OF PUREBREDS AND TWO-BREED CROSSES IN SWINE: FEEDLOT PERFORMANCE AND CARCASS MERIT[1]

R. K. Johnson, I. T. Omtvedt and L. E. Walters

Oklahoma Agricultural Experiment Station, Stillwater and U.S. Department of Agriculture, El Reno 74074

Summary

FEEDLOT performance of 941 barrows and gilts and carcass traits of 190 barrows of purebreds and crossbreds of the Duroc, Hampshire and Yorkshire breeds were evaluated for differences between purebreds and reciprocal crosses and for heterosis. Purebred and crossbred litters were farrowed contemporaneously at the Ft. Reno Experiment Station in the 1971 spring and fall farrowing seasons.

Rather distinct differences between the pure breeds were evident for most traits. In general, Durocs gained weight more rapidly than Hampshires and Yorkshires while Yorkshires were the most efficient pure breed. Hampshire barrows had less backfat, more loin eye area and more total yield of lean cuts than Duroc or Yorkshire barrows, however Duroc barrows were superior to the other breeds for quality scores of marbling, firmness and color.

Heterosis, defined as significant deviation from the average of parental breeds, was found for average daily gain on test (10.2%), age at 100 kg (5.2%) and average daily feed intake (5.9%). There was little evidence for heterosis for carcass measurements or yield of lean cuts. There was positive heterosis for marbling and firmness scores in crosses involving Durocs; however, Hampshire-Yorkshire crosses had negative heterosis for each of these traits.

Reciprocal differences between Duroc and Hampshire crosses were small and nonsignificant for all traits. However, most reciprocal differences in crosses involving Yorkshires were significant indicating a difference in the maternal influence of the three breeds.

Introduction

Although considerable work has been done involving swine crossbreeding, studies involving postweaning performance and carcass traits are limited. Most of the previous investigations were designed to evaluate heterosis and they provided little information regarding maternal influence or specific combining ability of reciprocal crosses. Pani *et al.* (1963) noted that Landrace x Poland China crossbred pigs were 4.1 kg heavier at 154 days of age than pigs produced by the reciprocal mating, but the difference was not significant. More recently Bereskin, Shelby and Hazel (1971) reported significant heterosis for carcass backfat, percent ham and percent ham and loin and considerable maternal variance for most carcass traits in crosses involving Durocs and Yorkshires.

The present paper provides information on carcass traits, growth rate and feed utilization of purebred and reciprocal crosses involving the Duroc, Hampshire and Yorkshire breeds. The objective of the study was to evaluate the purebred performance and the combining ability of the three breeds of swine.

Materials and Methods

Data were obtained from the first phase of the Oklahoma swine crossbreeding project being conducted at the Ft. Reno Experiment Station. In this phase purebred Durocs, Hampshires and Yorkshires were mated in all combinations to produce purebred and 2-breed cross pigs. Foundation herds of the three breeds are maintained at the Experimental Swine Farm at Stillwater. Foundation Duroc and Yorkshire herds were assembled in 1969 by sampling boars and gilts from several purebred herds of these breeds. The Hampshire herd was formed by purchasing boars from several sources and mating them to females

[1] Journal Article 2566 of the Agricultural Experiment Station, Oklahoma State University, Stillwater. Research conducted by the Department of Animal Sciences and Industry (Project 1444) in cooperation with Animal Science Research Division, Agricultural Research Service, U.S.D.A.

from the existing OK14 purebred research herd. Each year new boars are introduced into each herd in order to maintain a broad genetic base. Each foundation herd consists of about five boars and 30 sows and is maintained on a twice-a-year farrowing system. Replacement gilts and boars are selected primarily on growth rate, probe backfat thickness and soundness.

The present study includes 941 purebred and crossbred barrows and gilts produced in 180 litters (approximately 20 of each of the nine breeding groups) at Ft. Reno in the spring and fall farrowing seasons of 1971. Each season litters were produced by mating each of approximately six boars of each breed to two gilts of each breed. Purebred litters of each breed were also produced in the same seasons at Stillwater. Since there were fewer pigs raised in the purebred litters than in crossbred litters in the project, numbers on test were increased by transferring 294 purebred pigs (91 in the spring and 203 in the fall) farrowed at Stillwater to Ft. Reno. These pigs were of comparable breeding to those farrowed at Ft. Reno and were transferred at weaning and allotted to test with the Ft. Reno pigs. Data for growth rate and backfat thickness of gilts includes only the Ft. Reno born pigs while the feed records include all pigs. Forty Stillwater born pigs are also included in the 190 barrows which made up the random sample of barrows evaluated for carcass traits. Since the performance records for the purebreds from Stillwater were not significantly different from those of the same breeding farrowed at Ft. Reno, including these pigs in the feed efficiency and carcass analyses should not bias the results. The number of observations for the various traits by breed group is shown in table 1.

TABLE 1. DISTRIBUTIONS OF PIGS BY BREEDING GROUP FOR TRAITS MEASURED

Breed type[a]	No. of pigs for daily gain and age at 100 kg	No. of gilts for probe backfat	No. of pens for feed consumption and efficiency	No. barrows for carcass traits[b]
Duroc (D)	85	50	7	22 (22)
Hampshire (H)	65	38	7	23 (15)
Yorkshire (Y)	79	53	9	22 (4)
D x H	121	62	7	21 (0)
H x D	113	49	5	19 (0)
D x Y	135	71	7	20 (0)
Y x D	135	59	8	21 (0)
H x Y	92	38	7	21 (0)
Y x H	116	59	6	21 (0)
Total	941	479	63	190 (40)

[a] First letter designates breed of sire.
[b] Numbers in parenthesis are the number born at Stillwater.

The pigs were farrowed in confinement and weaned at 42 days of age. Pigs were given free access to creep feed at 21 days of age. Two weeks after weaning, the pigs were moved to the confinement finishing floor and allotted by breeding group in groups of about 15 pigs per pen. The pigs were given a 1-week adjustment period before being weighed on test. The pigs were self-fed a 16% protein milo-soybean meal ration from 9 weeks of age to 100 kg live weight. They were weighed off test weekly at which time all gilts were probed for backfat thickness. A sample of 10 to 12 barrows of each breeding group was randomly selected each season to be slaughtered and evaluated for carcass merit. About 10 barrows were slaughtered per week. Slaughter barrows were transported to the Oklahoma State University Meat Laboratory and held off feed and water for approximately 24 hr. prior to slaughter.

The feedlot performance traits investigated were average daily gain from the first day on test to 100 kg live weight, age at 100 kg, probe backfat thickness of gilts at 100 kg, pen feed efficiency measured in terms of kilograms gained per kilogram feed consumed and pen average daily kilograms of feed consumed per pig. Actual off test weights and ages were adjusted to a 100 kg live weight basis with an additive adjustment factor of 0.907 kg gain per day (conversion factors approved by National Association of Swine Records, January 1, 1970). Probed backfat thickness of the gilts was measured approximately 4 cm from the midline at the area of the first rib, last rib and last lumbar vertebra and the average of the three probes was used. The average probe was adjusted to a 100 kg basis with an adjustment factor of 0.0224 cm per kilogram live weight.

Carcass measurements included length from the anterior edge of the aitch bone to the forward edge of the first rib, the average of three backfat measurements taken down the midline in the same area as probe backfat and loin eye area measured between the 10th and 11th ribs. Carcass length, backfat thickness and loin eye area were adjusted to a 100 kg basis with additive adjustment factors of 0.14 cm, 0.0224 cm and 0.213 cm^2 per kilogram, respectively. Carcass lean yield was measured by the weight of closely trimmed hams, loins and shoulders and is expressed as a total lean cut weight. Total lean cut weight, expressed as a percent of chilled carcass weight, was also analyzed. Marbling, firmness and color of the *longissimus* muscle were evaluated at the 10th rib. All scoring in each season was done by the same person. A scale of 1 to 7 was used for each trait with a score of 1 indicating a loin devoid of marbling, very soft and pale in color. A score of 7 indicates loins abundant in marbling, very firm and very dark colored.

Data were analyzed by the least squares procedures for disproportionate subclasses described by Harvey (1960). The model for all traits included the effects of season, breed of sire, breed of dam and their interactions. Sex was added to the model for analysis of average daily gain on test and age at 100 kg; however, the interaction of sex with the other effects in the model was assumed negligible. In the analysis of total lean cut weight and percent lean of carcass weight the partial regression of slaughter weight was added to the model. Comparisons among breed groups were made by various linear functions of least squares means. More comparisons were made than there were independent degrees of freedom; therefore, all comparisons are not independent and the error rate over all comparisons is somewhat different than indicated by the levels of significance.

Because of the purebred pigs transferred from Stillwater to Ft. Reno and the method of sampling breeding groups for slaughter barrows, there were several cases where a sire had only one barrow in the slaughter sample. As a result, to add the effect of sire within breed of sire to the model would have made for difficult analyses so it was decided to ignore this effect. It would be expected that ignoring this effect would have its largest influence on tests of significance for the more highly heritable carcass traits. However, Bereskin *et al.* (1971) reported the effect of boars within breed of sire to be a nonsignificant source of variation for all carcass traits except loin eye area and percent ham and loin. In their analyses, ignoring the effect of sires within breed of sire would have had little influence on probability levels associated with tests of significance for other effects.

The average initial weight on test of pigs per pen ranged from 14.4 to 32.3 kg with a mean of 21.6 kilograms. In a preliminary analysis of these data, pen feed efficiency was regressed on the mean pen weight on test. This regression coefficient was almost zero, was nonsignificant and gave no evidence for including initial weight on test in the model for analysis of feed efficiency.

Results and Discussion

Analyses of Variance. Analyses of variance for feedlot traits and carcass traits are presented in tables 2 and 3, respectively. The effect of season was significant for all measures of feedlot performance and several carcass traits. On the average, pigs evaluated from spring-born litters gained faster and more efficiently than those from fall-born litters. Spring-born barrows had less total yield of lean cuts and somewhat higher quality scores, and the gilts and barrows farrowed in the spring had more probe backfat and carcass backfat than those born in the fall.

The effect of sex was highly significant for average daily gain and age at 100 kg as gilts gained 0.052 kg less per day and were 6.4 days older at 100 kg live weight than barrows.

Mean squares for breed of sire and breed of dam were significant for most traits. Significant breed of sire effects suggest genetic differ-

TABLE 2. MEAN SQUARES FOR MEASURES OF FEEDLOT PERFORMANCE

Source	df	A.D.G., kg[a]	Days to 100 kg	Probe backfat, cm	Gain/feed[b]	Avg daily feed intake, kg[a]
Season (S)	1	2.59*	25945.3**	8.37**	22.00**	81.23**
Sex	1	60.14**	9199.5**	....	.....	.....
Breed of sire (BS)	2	2.91**	394.3	3.79**	0.82*	7.17
Breed of dam (BD)	2	1.94*	1277.3**	4.58**	6.80**	36.99**
BS x BD	4	6.31**	3877.0**	0.37*	0.21	6.04
S x BS	2	2.95**	515.7	0.26	0.11	0.63
S x BD	2	2.19*	186.7	0.00	0.54	6.56
S x BS x BD	4	2.62**	1003.2**	0.41*	0.33	15.76**
Residual	922[c]	0.52	187.0	0.14	0.25	2.98

[a] Times 10^{-2}.
[b] Times 10^{-3}.
[c] Residual degrees of freedom for probe backfat=461, residual degrees of freedom for gain/feed and average daily feed intake=45.
* P≦.05.
** P≦.01.

TABLE 3. MEAN SQUARES FOR CARCASS TRAITS

Source	df	Carcass length, cm	Carcass backfat, cm	Loin eye area, cm²	Total lean cut yield, kg	Percent lean cut yield of carcass weight	Marbling score	Firmness score	Color score
Season (S)	1	3.54	0.649**	8.69	60.2**	2.6	14.3**	12.6**	1.00
Breed of sire (BS)	2	14.18**	3.067**	245.40**	59.4**	143.4**	77.0**	44.9**	4.81**
Breed of dam (BD)	2	13.98**	0.393*	27.13	9.8*	54.7**	34.4**	23.9**	7.94**
BS x BD	4	3.94	0.288*	8.85	5.5	10.2	14.0**	8.5**	3.42*
S x BS	2	0.37	0.232	17.07	2.6	0.7	2.7	2.2	0.48
S x BD	2	0.25	0.279	69.53**	23.8**	28.8**	17.1**	17.0**	6.84**
S x BS x BD	4	1.18	0.014	43.43**	5.1	10.2	0.8	0.5	1.23
Covariate[b]	1	...	.....	.....	94.0**	14.1	...	...	....
Residual	172[a]	2.01	0.096	12.18	2.8	4.8	1.6	1.5	0.86

[a] Residual degrees of freedom for total lean cut yield and percent lean cut yield of carcass weight=171.
[b] Regression on slaughter weight.
* $P \leq .05$.
** $P \leq .01$.

ences among breeds. Breed of dam mean squares also are influenced by genetic differences between the pigs, and in addition may be reflecting genetic maternal breed effects. For most measures of feedlot performance the breed of dam mean square was considerably larger than the breed of sire mean square. This would suggest a difference in the average maternal effect of the three breeds for these traits. For most carcass traits the breed of sire mean square was considerably larger than the breed of dam mean square. Perhaps this suggests a negative covariance between direct and maternal genetic effects. Cox and Willham (1962) have shown maternal effects in swine to be important for growth rate. Ahlschwede and Robison (1971a, b) found maternal effects were large for weight at 140 days of age and for backfat thickness at 72.7 kg in Durocs and Yorkshires and also reported large negative genetic correlations between direct and maternal effects for both traits. However, there is little information available on the relationship between direct and maternal genetic effects for most carcass traits. In contrast to the present study Bereskin *et al.* (1971) reported significant breed of dam effects for all carcass traits in a study involving crosses between Durocs and Yorkshires; however, breed of sire effects were significant only for carcass length. These workers concluded there was a large average difference in the maternal effect on carcass traits between these breeds.

Evidence for considerable non-additive genetic variance for growth rate, backfat thickness and quality scores is shown by a significant breed of sire by breed of dam interaction. This reflects the importance of heterosis for these traits and will be discussed in greater detail when specific comparisons are presented.

The interaction of season by breed of sire was significant only for average daily gain. In the spring season the average daily gain for pigs produced by Duroc, Hampshire and Yorkshire sires was 0.709, 0.713 and 0.691 kg per day, respectively. In the fall season pigs produced by Duroc, Hampshire and Yorkshire sires gained 0.718, 0.700 and 0.697 kg per day, respectively. The lack of season by breed of sire interaction for other traits is interpreted to mean that the average differences in breeding value for each trait between the sires of the three breeds was approximately the same each season.

Season by breed of dam interaction effects were significant for average daily gain and for several carcass traits. Pigs born to Duroc dams gained 0.03 kg per day faster in the spring than in the fall, while pigs born to Hampshire and Yorkshire dams gained the same in each season.

With the exception of loin eye area, the interactions for carcass traits were due to the change in magnitude of the difference between the breed of dam means for the two seasons and not a change in rank. In general, barrows produced by Yorkshire dams in the fall were superior in terms of carcass measurements but had lower carcass quality scores than spring-born barrows from Yorkshire dams. The loins from the barrows from Duroc dams ranked the highest in the spring, but they ranked the lowest among the fall carcasses.

Compared to the other breeds, the Yorkshire in the spring had a higher percentage of slow gaining, unthrifty pigs; consequently, these were seldom used in the slaughter sample. This could contribute to the season by breed of dam interactions obtained for carcass traits, however, more data are needed to assess the importance of these interactions.

Season by breed of sire by breed of dam effects were significant for growth rate, daily feed intake, probe backfat and loin eye area, suggesting a different amount of heterosis for spring-born and fall-born pigs. For all these traits except probe backfat and loin eye area the sign of the heterosis for all crosses was the same in each season and differed only in magnitude.

On the average, crossbred pigs had less probe backfat and larger loin eye areas than purebreds in the spring; while in the fall, the reverse was true. Crossbred pigs gained faster and consumed more feed than purebreds in both seasons; however, the difference between crossbreds and purebreds was greater in the spring than in the fall.

In general the differences between purebreds and between the reciprocal crosses for these traits were approximately the same each season. For this reason, the comparisons presented in the following section between purebreds, reciprocal differences and crossbred averages appear to be free of these interactions and these results may be applied to pigs born in either the spring or fall seasons. Thus these interaction effects mean that the amount of heterosis expressed for these traits differed among the various crosses in the two seasons. Whether these differences are real or not is difficult to determine. Kuhlers, Chapman and First (1972) found more significant interactions of purebred *vs.* crossbred by year than expected by chance alone for carcass traits, but this was not true for measures of performance. There appeared to be no obvious reasons for this interaction in the present study; however, those factors discussed above which may have contributed to season by breed of dam interaction may also have contributed to the three way interactions.

Least Squares Mean Comparisons. All comparisons among means found in tables 4 and 5 are the differences between means averaged over seasons. For all traits for which the interactions were discussed above, except probe backfat of gilts and loin eye area, the heterosis should be interpreted simply as the average heterosis over two seasons where it differed in amount each season but was in the same direction. Because the heterosis for probe backfat thickness and loin eye area differed in sign in the two seasons, little can be said regarding these two traits. This study will be repeated beginning in the spring of 1973 which will give additional information.

Feedlot Performance and Probe Backfat of Gilts. The least squares means for the nine breeding groups and specific comparisons among these means for feedlot performance and probe backfat thickness are presented in table 4.

Although purebred Durocs tended to gain faster and to reach 100 kg live weight faster than purebred Hampshires and Yorkshires, none of the differences between purebreds was significant except for age at 100 kg between Durocs and Hampshires. Durocs also had significantly more probe backfat than Hampshires and Yorkshires, while Yorkshire purebreds were significantly more efficient feed converters than Durocs or Hampshires and consumed less feed per day than both other breeds. This difference was significant only between Durocs and Yorkshires. Similar differences in growth rate between purebreds of these three breeds have previously been reported (Bruner and Swiger, 1968; Hale and Southwell, 1967; Quijandria, Woodard and Robison, 1970). However, the last two studies cited reported Durocs also gained weight more efficiently than the other two breeds; while in the present study, the Yorkshire was the most efficient pure breed.

There was significant heterosis expressed for average daily gain and age at 100 kg for all crosses with the amount of heterosis being very uniform for each specific cross. On the average, crossbreds gained 0.067 kg more per day and reached 100 kg 9.9 days sooner than

TABLE 4. LEAST SQUARES BREEDING GROUP MEANS AND SPECIFIC COMPARISONS AMONG THEM FOR MEASURES OF FEEDLOT PERFORMANCE AND PROBE BACKFAT THICKNESS OF GILTS

Item[a]	Avg daily gain, kg	Age at 100 kg	Probe backfat, cm	Kg gain/ kg feed	Avg daily feed intake, kg
			Means		
$\overline{X}$	0.705	183.0	3.12	0.313	2.31
D	0.670	187.0	3.51	0.300	2.37
H	0.657	192.7	2.95	0.307	2.22
Y	0.654	189.1	3.03	0.324	2.08
D x H	0.730	179.5	3.17	0.297	2.52
H x D	0.728	179.9	3.03	0.310	2.43
D x Y	0.740	178.5	3.02	0.331	2.24
Y x D	0.731	177.9	3.35	0.310	2.37
H x Y	0.735	177.9	2.80	0.345	2.13
Y x H	0.698	184.1	3.27	0.294	2.40
			Straightbreds		
D minus H	0.013	—5.7*	0.56**	—.006	0.15
D minus Y	0.016	—2.1	0.48**	—.024**	0.29**
H minus Y	0.003	3.6	—.08	—.017*	0.14
			Heterosis		
D x H & H x D	0.729	179.7	3.10	0.303	2.48
D and H	0.664	189.8	3.23	0.303	2.30
Difference	0.065**	—10.1**	—.13*	0.000	0.18*
D x Y & Y x D	0.736	178.2	3.19	0.320	2.31
D and Y	0.662	188.0	3.27	0.312	2.23
Difference	0.074**	—9.8**	—.08	0.008	0.08
H x Y & Y x H	0.717	181.0	3.04	0.319	2.27
H and Y	0.656	190.9	2.99	0.315	2.15
Difference	0.061**	—9.9**	0.05	0.004	0.12
Crossbreds	0.727	179.7	3.11	0.314	2.35
Straightbreds	0.660	189.6	3.16	0.310	2.22
Difference	0.067**	—9.9**	—.05	0.004	0.13**
			Differences between reciprocals		
D x H minus H x D	0.002	—.4	0.14	—.013	0.09
D x Y minus Y x D	0.009	0.6	—.33**	0.021*	—.13
H x Y minus Y x H	0.037**	—6.2*	—.47**	0.051**	—.27**
			Differences between crossbred averages[b]		
DH minus DY	—.007	1.5	—.09	—.017**	0.17*
DH minus HY	0.013	—1.3	0.07	—.016*	—.21**
DY minus HY	0.019**	—2.1	0.15**	0.001	0.04

[a] D=Duroc, H=Hampshire, Y=Yorkshire.
[b] DH=average of D x H and H x D, etc.
* P≦.05.
** P≦.01.

purebreds. Duroc-Hampshire crossbreds had 0.13 cm less probe backfat and consumed 0.18 kg more feed per day than the average of purebred Durocs and Hampshires and on the average crossbreds also consumed 0.13 kg more feed per day than purebreds. No other differences between crossbreds and purebreds for feedlot performance were significant.

In general crossbreds gain faster than purebreds (Carroll and Roberts, 1942; Gregory and Dickerson, 1952; England and Winters, 1953; Gaines and Hazel, 1957; Smith, Moorman and McLaren, 1960). The average advantage of crossbreds in rate of gain of 0.067 kg per day is somewhat higher than the difference of 0.05 and 0.04 kg per day reported by Whatley, Wilson and Omtvedt (1960) and Kuhlers *et al.* (1972), respectively.

In agreement with this study, Whatley *et al.* 1960) and Kuhlers *et al.* (1972) also reported a nonsignificant tendency for crossbreds to be more efficient in feed conversion than purebreds. However, in contrast to this study, Kuhlers *et al.* (1972) reported little difference in average daily feed consumption between crossbreds and purebreds.

TABLE 5. LEAST SQUARES BREEDING GROUP MEANS AND SPECIFIC COMPARISONS AMONG THEM FOR CARCASS TRAITS

Item[a]	Carcass length, cm	Carcass backfat, cm	Loin eye area, cm²	Total lean cut yield, kg	Lean of carcass weight, %	Marbling score[b]	Firmness score[c]	Color score[d]
				Means				
$\overline{X}$	77.84	3.08	31.49	39.37	56.3	4.40	4.94	4.90
D	76.55	3.21	31.24	38.77	54.9	5.56	5.92	5.26
H	77.89	2.71	33.65	40.80	58.5	3.10	3.80	4.44
Y	78.31	3.15	30.33	38.78	56.1	3.68	4.68	5.13
D x H	77.13	3.14	31.88	39.55	56.2	5.88	6.01	5.24
H x D	77.84	2.99	32.12	39.64	56.7	5.16	5.26	5.13
D x Y	78.18	3.02	32.07	40.08	57.2	5.60	5.80	5.15
Y x D	78.33	3.10	29.35	38.45	54.8	4.99	5.50	5.16
H x Y	78.65	2.81	34.21	40.43	58.7	3.18	4.27	4.76
Y x H	77.64	3.41	28.54	37.84	54.0	2.47	3.19	3.83
				Straightbreds				
D minus H	−1.34**	0.50**	−2.41*	−2.03**	−3.6*	2.46**	2.12**	0.82**
D minus Y	−1.76**	0.06	0.91	−.01	−1.2	1.88**	1.24**	0.13
H minus Y	−.42	−.44**	3.32**	2.02**	2.4**	−.58	−.88*	−.69*
				Heterosis				
D x H & H x D	77.49	3.07	32.00	39.60	56.5	5.52	5.64	5.19
D and H	77.22	2.96	32.45	39.79	56.7	4.33	4.86	4.85
Difference	0.27	0.11	−.45	−.19	−.3	1.19**	0.78**	0.34
D x Y & Y x D	78.26	3.06	30.71	39.27	56.0	5.30	5.65	5.26
D and Y	77.43	3.18	30.79	38.78	55.6	4.62	5.30	5.20
Difference	0.83**	−.12	−.08	0.49	0.5	0.68*	0.35	−.04
H x Y & Y x H	78.15	3.11	31.38	39.14	56.4	2.83	3.73	4.30
H and Y	78.10	2.93	31.99	39.79	57.3	3.39	4.24	4.79
Difference	0.05	0.18**	−.62	−.65	−.9*	−.57*	−.51*	−.49*
Crossbreds	77.96	3.08	31.36	39.33	56.3	4.55	5.01	4.88
Straightbreds	77.58	3.02	31.74	39.45	56.5	4.11	4.80	4.94
Difference	0.38	0.06	−.38	−.12	−.2	0.44*	0.21	−.06
				Differences between reciprocals				
D x H minus H x D	−.71	0.15	−.24	−.09	−.5	0.72	0.75	0.11
D x Y minus Y x D	−.15	−.08	2.72*	1.63**	2.4**	0.61	0.30	−.01
H x Y minus Y x H	1.01*	−.60**	5.67**	2.59**	4.7**	0.71*	1.08**	0.93**
				Differences between crossbred averages[e]				
DH minus DY	−.77*	0.01	1.29	0.33	0.45	0.23	0.02	0.03
DH minus DY	−.66*	−.05	0.63	0.46	0.10	2.70**	1.91**	0.89**
DY minus HY	0.11	−.05	−.67	0.13	−.35	2.47**	1.92**	0.86**

[a] D=Duroc, H=Hampshire, Y=Yorkshire.
[b] 1=devoid; 5=average; 7=abundant.
[c] 1=very soft; 5=average; 7=very firm.
[d] 1=pale; 5=dark pink; 7=very dark.
[e] DH=average of D x H and H x D, etc.
* $P \leq .05$.
** $P \leq .01$.

There was little difference between reciprocal crosses involving Durocs and Hampshires. However, Yorkshire females when mated to a boar of another breed produced pigs that were superior to the reciprocal cross for all measures of feedlot performance except age at 100 kg in crosses involving Durocs and Yorkshires. In crosses involving Durocs and Yorkshires only differences in probe backfat thickness and gain/feed between reciprocals were significant; however, all reciprocal differences involving Hampshires were significant. This suggests a favorable maternal influence of Yorkshire females for these traits as compared to Duroc and Hampshire females when mated to a boar of another breed. Gaines and Hazel (1957) also reported significant differences between reciprocal crosses. Pigs produced by mating Poland China boars to Landrace sows were far superior in growth rate to those produced from Landrace boars on Poland China sows.

In comparisons among the crossbreds (average of reciprocal crosses), crosses involving Yorkshires were significantly more efficient feed converters and consumed less feed per day than crosses among Durocs and Hampshires. When Durocs were involved in the cross, the pigs tended to grow faster and to have more probe backfat than when Durocs were not used in the cross. The differences of 0.15 cm in backfat and 0.019 kg per day in growth rate between Duroc-Yorkshire and Hampshire-Yorkshire were the only significant differences. Perhaps some caution should be used in interpreting these results since relatively small numbers of sires per breed are represented. Additional sires are needed before more definite conclusions can be made.

Carcass Traits. The least squares breeding group means and the specific comparisons among them for carcass traits are presented in table 5. All means for total yield of lean cuts and percent lean cuts of live weight are adjusted to the overall mean slaughter weight of 95.2 kilograms. The regression coefficients for yield of lean and percent lean cuts were 0.293 ± 0.051 kg and $-.00114 \pm 0.00066\%$ per kilogram live weight, respectively.

Rather large differences in carcass traits among the pure breeds are evident. Durocs were shorter than Hampshires and Yorkshires; however, Hampshires had less carcass backfat than Durocs and Yorkshires and exceeded them in loin eye area, total yield of lean cuts and percent lean cuts of live weight. There was little difference between purebred Durocs and Yorkshires for these traits. These differences among carcass traits of the three pure breeds agree very closely with reports in the literature (Hale and Southwell, 1967; Bruner and Swiger, 1968; Quijandria *et al.*, 1970).

Each of the quality scores of marbling, firmness and color ranked in the order of Durocs, Yorkshires and Hampshires. Differences between Durocs and Hampshires were significant for all three traits while the differences between Durocs and Yorkshires were significant for marbling and firmness scores. Yorkshires also had significantly higher firmness and color scores than Hampshires. Breed differences for quality scores are quite similar to those reported by Jensen, Craig and Robison (1967). Judge *et al.* (1959) and Otto (1962) also reported significant breed differences for meat color.

In general there was little evidence for heterosis for carcass measurements or amount of lean. Duroc-Yorkshire crosses were significantly longer than the average of the breeds that made up the cross, while the difference was significant for both carcass backfat and percent lean cuts of carcass weight for the Hampshire-Yorkshire crosses. The average of all crossbreds was quite well predicted by the average of the purebreds. Early work by Whatley *et al.* (1960) and Gregory and Dickerson (1952) revealed little difference between crossbred and purebred performance for most carcass traits. However, Bereskin *et al.* (1971) reported purebred Duroc and Yorkshire groups averaged 0.23 cm less backfat, 0.4% more ham and 0.28% more ham and loin than means of the reciprocal crossbred groups. Although not significantly so, purebred groups also had slightly shorter carcasses and smaller loin eye areas than means of crossbred groups. Differences between crossbred and purebred averages in the present study were in the same direction but not significantly different.

All crosses involving Durocs resulted in rather large positive heterosis for marbling and firmness scores; however, there was significant negative heterosis for these traits in Hampshire-Yorkshire crosses. There was considerable variation among crosses in the amount of heterosis expressed for color score; however, the difference between crossbreds and purebreds was significant only in the Hampshire-Yorkshire cross.

These data tend to support the conclusion that there is little heterosis for carcass traits as the average crossbred performance for most traits is predicted quite well by the average of the purebreds which made up the cross. There appears to be considerable heterosis expressed for carcass quality; however, the amount and direction seems to be dependent on the specific cross involved.

As with the feedlot traits, the carcass differences between reciprocal crosses involving Durocs and Hampshires were not significant for any trait; however, Yorkshire females, when crossed, produced barrows with carcasses superior to those produced by Duroc and Hampshire females when crossed. Several of the differences involving Durocs and Yorkshires were significant while all differences involving Hampshires and Yorkshires were significant. Reciprocal cross differences involving Durocs and Yorkshires are very similar to those reported by Bereskin *et al.* (1971) and support their conclusion that there is a rather large maternal influence for carcass traits.

With the exception of carcass length and quality scores, none of the differences between the crossbred averages were significant. Duroc-Hampshire crosses were shorter than both Duroc-Yorkshire crosses and Hampshire-Yorkshire crosses. When Durocs were used in the cross either as sires or dams, there was a significant (P⩽.01) increase in each quality score over crosses which did not involve Durocs.

Literature Cited

Ahlschwede, W. T. and O. W. Robison. 1971a. Prenatal and postnatal influences on growth and backfat in swine. J. Anim. Sci. 32:10.

Ahlschwede, W. T. and O. W. Robison. 1971b. Maternal effects on weights and backfat of swine. J. Anim. Sci. 33:1206.

Bereskin, B., C. E. Shelby and L. N. Hazel. 1971. Carcass traits of purebred Durocs and Yorkshires and their crosses. J. Anim. Sci. 32:413.

Bruner, W. H. and L. H. Swiger. 1968. Effects of sex, season and breed on live and carcass traits at the Ohio swine evaluation station. J. Anim. Sci. 27:383.

Carroll, W. E. and E. Roberts. 1942. Crossbreeding in swine: Does it offer an effective method for improvement of market hogs? Ill. Agr. Exp. Sta. Bull. 489.

Cox, D. F. and R. L. Willham. 1962. Systematic fostering experiments in swine. J. Anim. Sci. 21:366.

England, D. C. and L. M. Winters. 1953. The effects of genetic diversity and performance of inbred lines *per se* on hybrid vigor in swine. J. Anim. Sci. 12:836.

Gaines, J. A. and L. N. Hazel. 1957. Differences in litter size and growth rate among purebred and crossbred swine. J. Anim. Sci. 16:1066. (Abstr.).

Gregory, K. E. and G. D. Dickerson. 1952. Influence of heterosis and plane of nutrition on rate and economy of gains, digestion and carcass composition of pigs. Mo. Agr. Res. Bull. 493.

Hale, O. M. and B. L. Southwell. 1967. Differences of swine performance and carcass characteristics because of dietary protein level, sex and breed. J. Anim. Sci. 26:341.

Harvey, W. R. 1960. Least-squares analysis of data with unequal subclass numbers. U.S.D.A. Pub. A.R.S. 20–8.

Jensen, P., H. B. Craig and O. W. Robison. 1967. Phenotypic and genetic associations among carcass traits of swine. J. Anim. Sci. 26:1252.

Judge, M. D., V. R. Cahill, L. E. Kunkle and W. H. Bruner. 1959. Pork quality. I. Influences of some factors on pork muscle characteristics. J. Anim. Sci. 18:448.

Kuhlers, D. L., A. B. Chapman and N. L. First. 1972. Estimates of genotype-environment interactions in production and carcass traits in swine. J. Anim. Sci. 35:1.

Otto, E. 1962. Determining color and muscle fibre diameter of meat and the effects of breed, sex, sire and dam on them. VIII. Int. Congs. Anim. Prod. III. 211. (*In* Animal. Breed. Abstr. 31:87).

Pani, S. N., B. N. Day, L. F. Tribble and J. F. Lasley. 1963. Maternal influence in swine as reflected by differences in reciprocal crosses. Mo. Agr. Exp. Sta. Res. Bull. 830.

Quijandria, B., Jr., J. R. Woodard and O. W. Robison. 1970. Genetic and environmental effects on live and carcass traits at the North Carolina swine evaluation station. J. Anim. Sci. 31:652.

Smith, H. J., R. P. Moorman and J. B. McLaren. 1960. Performance of straightbred and crossbred swine. J. Anim. Sci. 19:1227. (Abstr.).

Whatley, J. A., Jr., S. P. Wilson and I. T. Omtvedt. 1960. Performance tests with purebred and crossbred pigs from two lines of breeding. Okla. Agr. Exp. Sta. Mics. Pub. 57:50.